

Optical Imaging of the Nearshore

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LONG-TERM GOAL

The long-term goal of nearshore processes research has been to develop a predictive understanding of the fluid dynamics of a random wave field shoaling over the complicated bathymetry of a natural beach, and the response of the beach to those overlying wave and current motions [*Holman, et al.*, 1990]. Success requires advances in our understanding of nearshore physics, improvement in our capabilities for numerical modeling, and development and testing of methods for the rapid collection of the data required for model initial and boundary conditions and for data assimilation.

OBJECTIVES

It is apparent that the predictive capability of current and future nearshore models is more limited by the availability of input data (the data starvation problem) than by weaknesses in our understanding of the physics or in our modeling know-how. Thus, our program continues to develop optical remote sensing methods to estimate the suite of important nearshore variables and to study the dynamics revealed by those measurements.

APPROACH

The optical remote sensing methods developed over the years through the Argus Program lie at the heart of nearshore oceanographic research not just at the Coastal Imaging Lab, but also for an increasing global research community [*Davidson, et al.*, 2007; *Holman and Stanley*, 2007]. Our research continues along two parallel themes: development of robust methods for making critical nearshore environmental measurements and understanding the dynamics revealed by those measurements. By the nature of the data collection methods, we are usually able to study spatial variability over much larger domains, with higher spatial resolution and over longer time spans than have been studied using arrays of traditional in-situ sensors. On the other hand, surface optical measurements are often related to simple geophysical variables in indirect ways that require study. Importantly, optical methods developed under Argus can be readily transitioned to mobile platforms like UAVs if imagery can be properly geolocated. Work with NATO colleagues using the Raven, a standard operational platform, found that the use of co-registration to a ground map such as a satellite image provided adequate geometric control if shorelines were part of images [*Pennucci, et al.*, 2007].

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WORK COMPLETED

Our work has continued on optical polarimetry with the installation of “Polly”, a camera system capable of collecting rapid time series measurements of the degree and azimuth of linear polarization (DOLP and AOLP) as part of the Argus Program (Figure 1). The instrument is currently taking routine collections at Duck, NC, of both channels as well as of bore-sighted multi-spectral imagery as a testing and development data set. The primary target products will be sea surface elevation field versus time, foreshore beach slope data and potentially foreshore water content.

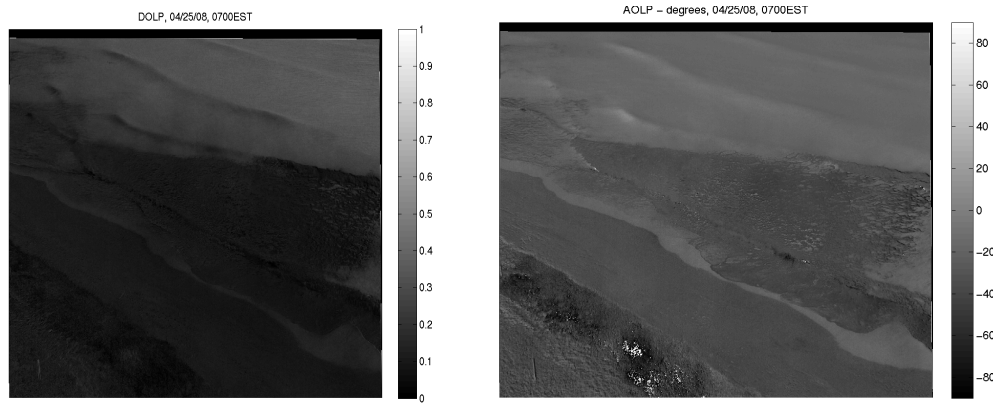


Figure 1. Example DOLP and AOLP images from the Duck polarimetry data. Breaking waves are essentially non-polarizing, in contrast to non-breaking waves. Wave-associated slope-variations are obvious in the AOLP image.

Bathymetry data is a key input to any nearshore model and is notoriously difficult to measure remotely, for example in denied areas or for long-term observing systems where in-situ sampling is impossible or prohibitive. Adequate knowledge of bathymetry is likely *the* limiting factor in the performance of nearshore models. Remote sensing methods have been developed in the past that exploit wave celerity observations to invert for underlying bathymetry, but these methods require difficult-to-obtain “motion imagery”, or time series of images, to make the required celerity measurements. We have just completed development of a method for estimating nearshore bathymetry based solely on the refractive turning of imaged waves [*Splinter and Holman*, in review]. While only appropriate to narrow-band swell conditions with significant refraction signals (usually associated with semi-enclosed seas), the method has the distinct advantage of requiring only single image snapshots, the kind that are widely available at many locations of interest. Synthetic tests show that the technique is capable of RMS accuracies of order 10cm (Figure 2).

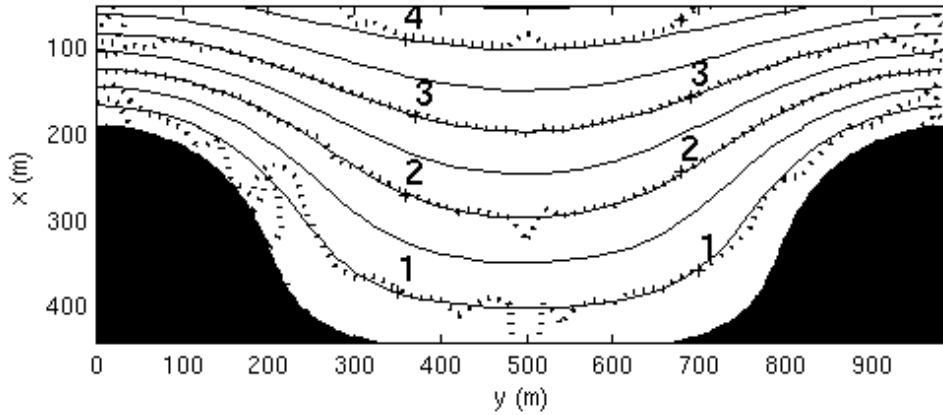


Figure 2. Synthetic test of refraction-based bathymetry estimation. Solid lines are true bathymetry, dotted are estimates from the refraction method, assuming an offshore wave of 8 s period and 30° angle of incidence. The RMS error was 0.28 cm, dominated by shallow regions near the shoreline or lateral boundaries.

We are also routinely collecting time series image data from the Duck Argus Station that are being analyzed to provide daily bathymetry estimates based on celerity observations. The methodology was developed by Plant et al [Plant, et al., 2008] under the Beach Wizard program and features a tomographic approach with robust statistical processing including a Kalman filter time smoothing. These data will be used to further develop and test the initial algorithms. The ultimate product of this work should be bathymetry products available routinely on the web.

In 2005, a joint US-Brazil field experiment was held at Casino Beach in Southern Brazil to investigate the changes in dynamics associated with accumulation of anomalous viscous muds that occasionally inundate the nearshore region. While no mud events occurred during the field experiment, a number have been subsequently recorded by an Argus Station that was installed (by others) as part of the program. A Brazilian student, Pedro Pereira, began a one-year visit in spring, 2008, focused on analyzing and developing models based on this observed data set (e.g. Figure 3). The CIL has been substantially involved in support and mentoring in this study.

Finally, our collaborations with Dr. Tuba Özkan-Haller through graduate student Greg Wilson have continued. This work concentrates on understanding the 2DH dynamics of alongshore-variable bathymetries typical on ocean coasts including the assimilation of fluid observations to invert for changing bathymetry (discussed more completely in the annual report of Özkan-Haller).

IMPACT/APPLICATION

Optical remote sensing is an obvious solution to the large data needs to nearshore observing systems. Work such as the robust bathymetry estimation methods begun in the Beach Wizard program are becoming standard tools for both the nearshore and the Navy METOC communities. Observations from Argus stations have changed the way scientists think about the nearshore, particularly the time evolution of the fluid-bathymetry system.

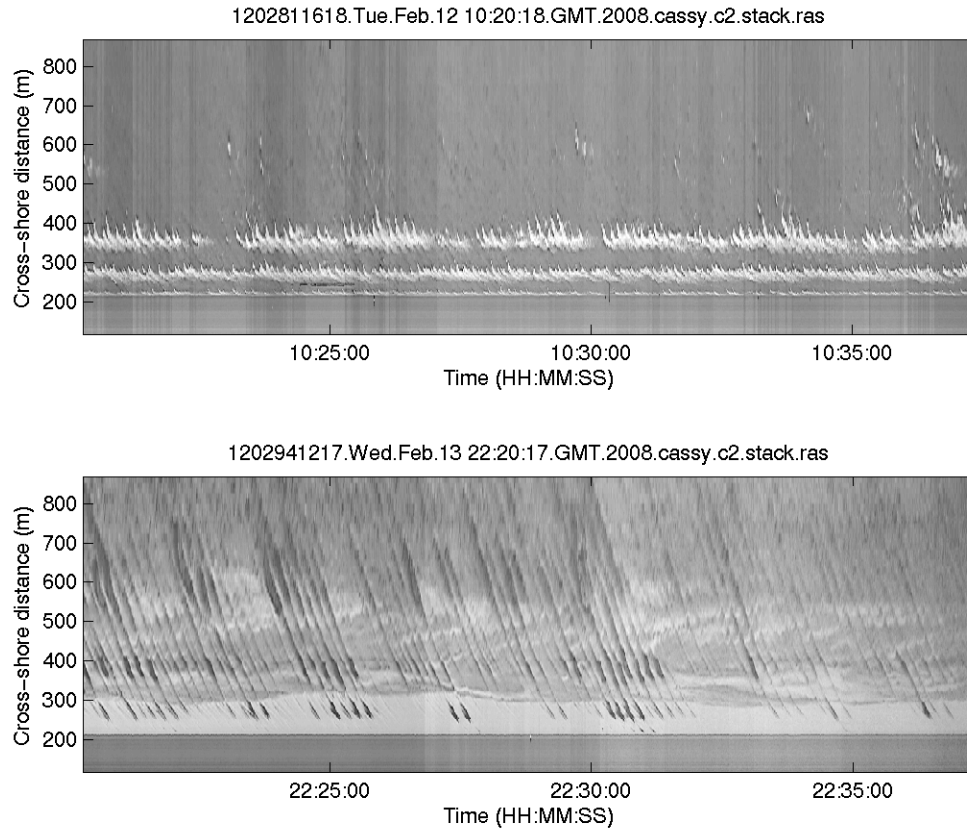


Figure 3. Time stacks showing onshore wave motion for an example cross-shore transect at Casino Beach, Brazil. The upper figure shows typical conditions, with waves breaking over two nearshore sand bars. The lower figure, collected 1.5 days later after the start of a mud event shows extreme attenuation of the incident waves.

TRANSITIONS

Argus technology or spin-offs have been at the heart of many current Navy research efforts into practical optical remote sensing. This has included the VISSER program by Dr. Todd Holland at NRL-SSC and connections through previous LRS efforts and follow-ons. Recently this work has expanded to explore the applicability of Argus methods to moving platforms such as small UAVs. This work is collaborative with NRL-SSC as well as the NATO Forward Eyes program run by Dan Conley. We continue collaboration with the U.S. Army Corps of Engineers both through Bill Curtis at Vicksburg and through the FRF on a variety of Argus issues and with the USGS in both research and applications-based work. Argus was the focus of the recently completed CoastView European Union program featuring the integration of Argus into standard Coastal Zone Management practice. Argus has been transitioned to commercial availability through transition agreements between OSU and Northwest Research Associates (for North America) and Delft Hydraulics (for the rest of the world).

RELATED PROJECTS

- 1 - Joint work with Dr. Todd Holland, NRL-SSC
- 2 - Collaboration with the WSC at Navocean on nearshore remote sensing

- 3 – LRS follow-on efforts, particularly UAV development
- 4 – Numerous collaborations with the Field Research Facility

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PATENTS

None

HONORS/AWARDS/PRIZES

OSU Alumni Association Distinguished Professor Award, 2007.